With Dr. Waller's complimen

SUMMARY

OF THE

PRINCIPAL PHYSIOLOGICAL RESEARCHES

OF

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In 1849 Dr. Waller discovered a new process for investigating the Nervous System, founded on the disorganization of the distal end of a divided nerve. By means of the fatty disorganization thus produced, he was enabled to detect at any point of its course below the point of section, a disorganized nerve-tube, however minute, in the midst of other sound fibres.

In this manner was accomplished a result equivalent to the injection into the nerve-tube of dark, granular matter, which had been in vain attempted by anatomists, such as Rusych, Bendz, &c., the former of whom states that "he *would have nothing further to wish for than to inject nerves as he had succeeded with blood-vessels.*" (See Cruveilher's Anatomy —" Système Nerveux.")

Dr. Waller first applied the process to investigate the exact distribution of the glossopharyngeal and hypoglossal nerves in the papillæ, and other structures of the tongue. (*Vide* " Phil. Trans.," 1850.) At the same time he pointed out its universal application to all the nerves, instancing those of the brain as an example.

Dr. Waller applied to the Royal Society for a grant of money to enable him to carry out the application of his new process in 1850. In 1853 the Council of the Royal Society acceded to this request by making him a grant from the Government fund for this purpose.

This process was more fully described in a letter to the Académie des Sciences, Nov. 1851. ("Comptes Rendus," Dec. 1st, 1851) entitled—"Nouvelle Méthode Anatomique pour l'Investigation du Système Nerveux," inserted in the "Comptes Rendus de l'Académie," and in the "New Quarterly Journal of Medical Sciences."

The various anatomical questions to which this process is applicable are very numerous—such, for instance, as the exact determination of the distribution of a nerve at its peripheral extremities, the structure of any nervous plexus, the arrangement of nerve-fibres in an anastomosis; in fact, almost every point where an exact knowledge of the arrangement of the elementary fibres of any nerve is to be decided; and when the ordinary means of investigation are insufficient, this process may be advantageously employed to determine the question.

Figs. 1 and 2 illustrate the manner in which the nerve becomes changed by section.

FIG. 1.

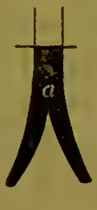


FIG 2.

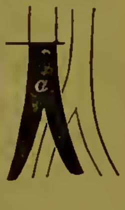


Fig. 1 represents a nerve after its division, the blackened portion (*a*) being the disorganized distal end below the line of section, and the upper unaltered portion being connected with the central organs.

Fig. 2 is a mixed nerve, where the fibres of one source only have been divided, leaving the fibres of the other source unaltered and mixed intimately with the disorganized fibres, but perfectly distinguishable from them.

It may be remarked that the discovery of this method was not by an isolated or fortuitous observation, but was the result of a series of researches on the peripheral extremities of the nerves of the tongue on the frog and on man.

See 1st. *Philosophical Magazine*, October, 1846,—"On the Examination of some of the Tissues of the Animal Frame, as observed in the Tongue of the Living Frog;"—2nd. "Microscopic Examination of the Papillæ and Nerves of the Frog's Tongue" (*Philosophical Magazine*, 1847);—3rd. "Development of the Mouth and Tongue of the Frog" (*Philosophical Magazine*, January 7, 1851);—4th. "Minute Structure of the Frog's Tongue" (*Philosophical Transactions*, Part I., 1849);—5th. "On the Structure of the Papillæ of the Human Tongue" (*Proceedings*, *Royal Society*).

But besides the advantages presented by this method of investigation for the solution of anatomical questions, it has been the means of elucidating numerous physiological questions relating to the nervous system which had previously eluded the researches of physiologists who were destitute of this mode of inquiry.

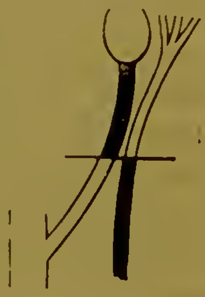
Such, for instance, are the functions and origin of the sympathetic nerve, the regeneration of nerves and restoration of their functions, the functions of spinal ganglia, and the functions of the spinal accessory and vagus nerves,—all of which questions have been either finally determined or considerably elucidated by the application of this new mode of research.

Functions and Origin of Sympathetic.

In order to solve the much-debated question of the origin of this nerve, we have to rely upon the fact that, while the *distal* portion of a divided nerve becomes disorganized, its *central* end remains *normal*. This fact, which had been generally admitted, though not demonstrated, and known under the name of the law of the centres, was found by Dr. Waller to hold good in all cases where the divided nerves were examined, even a considerable time after section. (*Vide* "Comptes Rendus," October, 1851, and December, 1851.)

By this means it was easy to determine the course of a nerve, whether ascending or descending, according as the disorganized portion was situated above or below the point of section. Applied to the cervical sympathetic its upper portion alone was found to be disorganized, whilst it lower portion remaine dnormal; consequently the course of the cervical sympathetic is from below upwards, while that of the vagus by its side, where the disorganized portion was below the point of section, is a descending course (see fig. 3), where, on the left, is the sympathetic nerve attached to its first ganglion above and to the spinal cord below, and on the right is the vagus nerve.

Fig. 3.



By following out the clue thus afforded, the nerve was traced upwards into the iris, and downwards into the dorsal region of the spinal cord, where it was found that there existed an extensive region, capable by galvanic excitation of producing dilitation of the pupils. ("Comptes Rendus," Oct., 1851.)

It was from the want of a clear guide of this sort that so little advantage had been derived form the researches of Petit, Molenelli, Reid, Biffi, and Valentin, in developing the motor functions of the cervical sympathetic, and its spinal origin.

These researches on the sympathetic, for which M. Budge and Dr. Waller obtained the Monthyon Prize, for experimental physiology of 1852, quickly led to Bernard's discovery of the increased temperature of the ear, attendant on the section of the corresponding sympathetic, which M. Bernard informed Dr. Waller he was acquainted with, but was unable to explain, until Dr. Waller's new process had shown the ascending course of the cervical sympathetic.

Thus one clear and precise experiment founded on an anatomical basis, has been the means of leading the way to all the knowledge we possess respecting the vaso-motory nerves.

Regeneration of Nerves

By reason of its practical importance very numerous researches had been made by Fontana and others on the regeneration of nerve-fibres, but in all their researches the attention of these physiologists was directed to the reproduction of nerve-fibres in the *cicatrix between the divided ends,* and they completely omitted the examination of the *distal portion* of the nerve, where the most important changes take place, and where the solution of the question must be sought. Dr. Waller was the the first to point out the general rule, that, after division of a nerve the distal end becomes completely disorganized before reunion takes place. Dr. Waller likewise came to the conclusion that fresh nerve-tubes were found in this distal end, and that they were formed by developing from the centre towards the periphery.—(*Vide* "Nouvelle Méthode," p. 24, § 16.)

Their characters are the following: they are pale, of a finely granulated structure, probably possessing an external membrane, which is soluble in acetic acid, destitute of double outline, generally $0,^{mm}002$ diam., and offering at variable intervals fusiform nuclei about $0,^{mm}02$ in length, parallel to the axis of the fibres.—("Comptes Rendus," 15th March, 1852.)

"After a double section of a nerve, the fibres are more rapidly formed in the middle portions than in the more distant segment of the nerve."—(*Vide* "Comptes Rendus," May, 1852.)

"After the lapse of three days after section of the sciatic nerve of a pigeon, the extremity of the *central portion* presented a swelling, *already containing new nerve fibres.*"

"Six months after section of a nerve it was found that many of the new fibres presented double outlines."—("Comptes Rendus," 15th March, 1852.)

Dr. Waller's researches were confirmed in all the principal points by those made subsequently by Professor Bruch, who likewise observed the formation of new fibres with the above characters, whose development proceeded from the centre outwards; he likewise observed new fibres formed in the extremity of the central portion three days after section.

Subsequent observers have confirmed most of the above statements, although they have interpreted them differently. Dr. Waller's observations on the regeneration of nerves are described in three memoirs, inserted in the "Comptes Rendus" of the Academy of Sciences, Paris, Dec. 1, 1851; March 15, 1852; and May 3, 1852.

Observations on the Spinal Ganglia.

The functions of the spinal ganglia had not in the least degree been elucidated by the researches of Sir C. Bell and his successors. Nor was it possible to subject them to the ordinary means of inquiry, because we possessed no power of examining their action, as in the case of the motor nerves, on account of their becoming completely inert and insensible as soon as they are separated from the central parts.

But when we subject them to the new means of inquiry, we obtain a series of novel and unexpected results, which have opened up a new field of research.

The principal results are:—

1st. Section of the nerve up to the ganglion causes disorgan zationof the distal end as far as the ganglion.

2nd. Section of the posterior root causes disorganization of the spinal portion only.

3rd. The consequence is, that the ganglion evidently possesses the power of maintaining the nutrition of all those parts of the nerve which remain in connection with it. It is thus a kind of centre of nutritive or trophic force of which previously we had not the least idea. The spinal cord itself exerts no sustaining influence whatever on the posterior root, which, when separated from the ganglion, is disorganized with the same speed as an ordinary distal segment. The anterior root alone has its nutrition maintained by the spinal cord, and becomes disorganized as soon as it is separated from the spinal cord.

All the principal points of Dr. Waller's observations on the spinal ganglia and roots are represented in the accompanying figures.

Fig. 8.

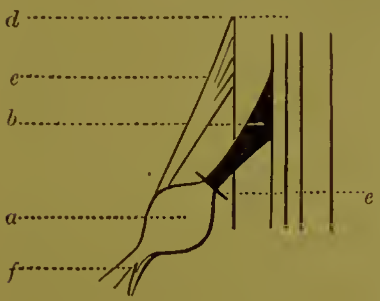


Fig. 9.

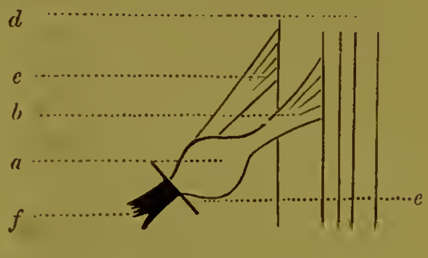


Fig. 10.

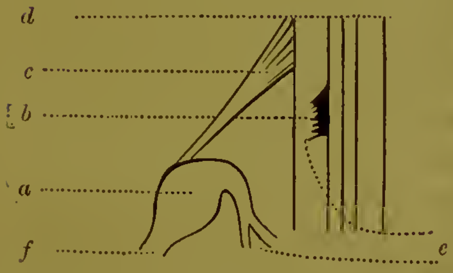


Fig. 11.

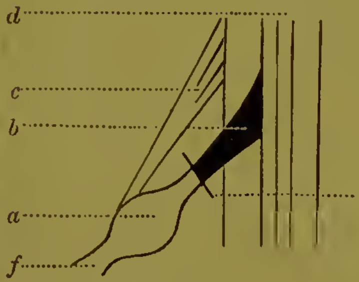


Fig. 12.

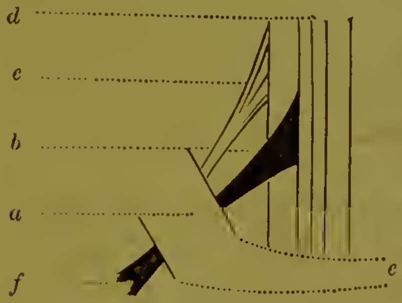


Fig. 13.

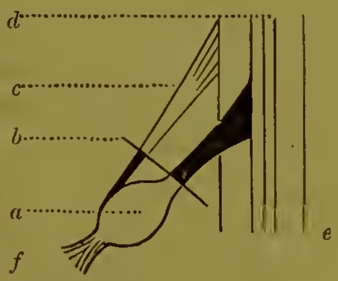


Fig. 8 represents the division at (*e*) of the posterior root near the ganglion, causing disorganization of the root, although still connected with the spinal cord; the ganglion (*a*), the anterior root (*c*), and the mixed nerve (*f*), all remaining normal.

Fig. 9 represents section of the mixed nerve beyond the ganglion, disorganization ensuing throughout its whole extent.

Fig. 10 is the posterior root, torn away from the cord ; (*b*) portion of the posterior root disorganized ; (*a*) ganglion with unaltered posterior root attached ; (*f*) mixed nerve ; (*c*) anterior root, normal.

Fig. 11. Division made on posterior root half-way between the spinal cord and ganglion, showing that the half of the posterior root connected with the ganglion is normal, while that attached to the spinal cord becomes disorganized.

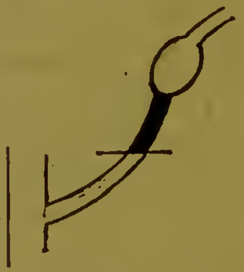
Fig. 12 represents the effects of extirpation at (*e*) of the ganglion, and motor fibres beneath it ; (*b*) disorganized posterior root ; (*c*) normal anterior root, its structure being kept up by the spinal cord, although the portion beneath the ganglion has been removed ; (*f*) mixed nerve disorganized.

Fig. 13. Division of both roots, producing disorganization of posterior root (*b*) above the section, and of anterior root (*c*) below the section ; mixed nerve (*f*), consisting of motor fibres disorganized, and of sensory fibres normal.

The above figures were first made to illustrate the manuscript memoir on the ganglia, which was sent to the Academy of Sciences previously to their award of the Monthyon prize to Dr. Waller. They have been introduced by M. Bernard into his "Leçons sur le Système Nerveux," 1858, where he gives a brief account of Dr. Waller's researches.

When applied to other ganglia, results are obtained which differ from those of the spinal ganglia. Thus, with the first cervical sympathetic, the disorganization extends into the ganglion without traversing it ; while, on the contrary, the opthalmic and the sphero-palatine ganglia offer no obstacle to the disorganizing process which extends beyond and through them, as seen in fig. 6, which represents the cervical sampathetic divided midway between the first cervical ganglion and the spinal cord ; the blackened portion shows disorganization from the line of section up to the ganglion, above which the nerve is normal.

Fig. 6.



Extract from the Comptes Rendus of the Academy of Sciences, Paris, No. 5, (February 2nd, 1857).

"*Report upon the Completion* (*Concours*) *for the prize of Experimental Physiology for the year* 1856." (*Translation.*)

MONTYON FOUNDATION.

(Commissioners — *MM. Flourens*, *Rayer*, *Serres*, *Milne Edwards*. *Cl. Bernard*, Reporter.)

There exist two kinds of facts: those which, to a certain extent may be foreseen, introducing into science more exact ideas, filling up gaps, and finally diffusing light over objects more or less obscure; the others, on the contrary, being unexpected, strike especially by their novelty, and have generally the extraordinary privilege of widening the field of science less by the immediate solutions which they offer, than by the new ideas which they suggest, or by the important questions to which they give birth.

Since the beginning of this century, the physiology of the nervous system has made rapid progress, and has been enriched with brilliant discoveries both on the functions of the nerves, and on the various parts of the nervous centres.

Nevertheless there still exist peculiar bodies on the course of the posterior roots of the spinal nerves, which have received the name of intervertebral ganglia, on the functions of which all past researches have shown us absolutely nothing. The experimental result on which the committee has now to pass its judgment is a first landmark placed in this unknown region of Physiology.

The observations about to be described have all been made on the second cervical pair of nerves, whose ganglion may be reached in some animals without opening the vertebral canal, and consequently without denuding the spinal cord.

The experiment is as follows:—After having cut the two roots of the above-mentioned pair of nerves, between the spinal cord and the ganglion, the animal (cat) is allowed to survive for a few days, when the structural alterations which have taken place in the divided ends of the nervous roots are examined. We then perceive in the posterior root, which alone is possessed of a ganglion, that its central portion, remaining in connection with the spinal cord, consists of nervous elements in a state of disorganization, and having undergone the granular transformation ; whereas the distal end, remaining in connexion with the ganglion consists, on the contrary, of nervous elements retaining all their normal texture, evidently showing that continuity of the nerve with the spinal cord does not prevent its becoming disorganized, whereas its connection with the intervertebral ganglion suffices to prevent it from becoming altered. But what is equally remarkable, the phenomenon takes place in the divided ends of the anterior spinal roots in an exactly inverse manner from the former. For in this instance the central portion connected with the spinal cord retains its normal structure, whilst its distal end becomes disorganized and reduced to a granular state. We therefore clearly arrive at this surprising conclusion, which could never have been suspected beforehand; viz., that the spinal cord confers on the anterior root that unknown vital power, whereby its elements resist granular disorganization; whereas, for the posterior root, on the contrary, this preservative power is no longer an attribute of the spinal cord, but resides in the ganglion.

The author of this beautiful experiment is Dr. Waller, a Physiologist well known to the Academy of Sciences, which already has awarded to him the prize of Experimental Physiology, in common with Dr. Budge, in 1852.

The experiments of Dr. Waller on the ganglia of the cerebro-spinal nerves have been continued for several years, and have been repeated in various ways; they have always given analogous results, and have led their authors to the conclusion, that the function of the intervertebral ganglia is that of presiding over the nutrition of the nerves which are in continuity with them.

The principal fact, that of the granular disorganisation of the central end of the posterior root, and the preservation of the central end of the anterior root of the same, has been verified by the committee, which, without wishing to pronounce upon any interpretation of the phenomenon, and judging the experiment alone, has considered that the important results obtained by Dr. Waller are destined to be the commencement of a series of new investigations which cannot fail to be undertaken, on such mysterious properties as those of the various ganglia of the animal economy.

Consequently the committee has unanimously granted to Dr. Waller the Prize of Experimental Physiology—(2,000 francs).

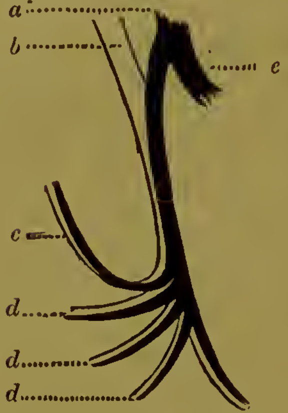
Functions of the Vagus and Spinal-accessory nerves.

If from among the various nerves of the human body we were called upon to point out that which has most exercised the patience and ingenuity of anatomists and physiologists, we should at once indicate the vagus. Its distribution to the larynx, the heart, the lungs, and the stomach, shows us at a glance the important nature of its functions. At its origin it is formed by roots springing from the medulla oblongata, to which are added afterwards a considerable branch from the accessorius, which joins and mingles with the pure vagus with which its fibres become intimately blended. The problem to be solved, therefore, is the precise functions of each or either, *i. e.* the accessorius or pure vagus before their anastomosis.

In ordinary circumstances nothing would be more simple than to uncover the nerves, and to galvanize each separately, as in the case of an ordinary spinal pair. But here the case is different; in their origin these nerves are so close to the medulla oblongata and the blood-vessels, that any such operation is quickly fatal, and the irritation of the minute roots of each nerve in close proximity, renders it impossible to obtain any precise results.

Bischoff's attempts at division of the roots of the accessorius rendered it probable that it gave motor fibres to the vagus which were distributed to the larynx. So far, the previsions of Sir C. Bell were confirmed which compared the intimate branch to the anterior motor branch of a spinal pair, and the vagus, with its ganglion, to the posterior roots. M. Bernard had, however, succeeded in entirely destroying the accessorius by traction on its external branch, and has arrived at the conclusion that all the fibres of this nerve were distributed to the larynx for the production of sound, while other fibres from the pure vagus governed certain nutritive or organic functions connected with respiration. For the purpose of determining the question more exactly, we have to consider the annexed Fig. 7, where *a* is the spinal accessory nerve, disorganized; *e*, external branch of same; *b*, pure vagus normal; *c*, recurrent nerve; *d d d*, cardiac and gastric branches.

Fig. 7.



In order to separate the functions of the one from the other, we require to destroy all the fibres of the accessorius and leave the others intact, which has been done most effectually by Dr. Waller's process; first destroying the accessorius on Bernard's plan, and afterwards allowing the animal to live sufficiently long for the fatty disorganization to take place, or about seven or eight days. The vagus being then galvanized at any part of its length, Dr. Waller finds it impossible to affect either the action of the heart or of the stomach, and the only result is to cause slight movements of the larynx.

It is, therefore, evident that Sir C. Bell's ideas respecting this nerve are in a great measure demonstrated by this experiment, the only exception being with regard to certain motor fibres of the larynx, which, it may be surmised, are derived from some anastomotic source, and, therefore, not contained in the vagus at its origin. (*See Proceedings*, *Royal Society*, vol. 8, page 69.)

In order to facilitate reference to most of the memoirs which Dr. Waller has published, the following particulars are subjoined ;—

1. Examination of some of the tissues of the animal frame, as observed in the tongue of the living frog.—*Philosophical Magazine*, Oct. 1846.

2. Microscopic examination of the papillæ and nerves of the frog's tongue.—*Philosophieal Magazine*, 1847.

The object of this paper was to show the minute structure of the fungiform and conical papillæ of the tongue of the frog, and the fundamental differences of the structure and functions which exist between them.

3. Development of the mouth and tongue of the frog.—*Philosophical Magazine*, January, 1851.

In this paper was demonstrated the fact of the *progressive increase in the number and size* of the nerve tubes in the fungiform papillæ, with the age of the animal.

4. On a new means of diagnosis of the affections of the nervous trunks.—*London Medical Gazette.*

5. Observations on the physiology of vision, and on the luminous spectra excited by pressure on the retina, applied as a means of diagnosis for diseases of the retina and optic nerve.

6. On the compression of the carotids, and its effects on headache, epilepsy, hysteria, &c.—*Journal of Psychological Medicine* (edited by Dr. Forbes Winslow), 1848.

7. Minute structure of the papillæ of the frog's tongue.—*Philosophical Transaetions*, Part I., 1849.

8. Experiments on the section of the glossopharyngeal and hypoglossal nerves, and observations on the alterations produced in the structure of their primitive fibres.—*Philosophical Transaetions,* Part II., 1850.

9. On the absorption of various substances through the skin of the frog.—*Froreips Tagsberiehte*, 1851.

10. Recherches sur l'action de la partie cervicale du grand sympathique et d'une portion de la moelle épinière sur la dilatation de la pupille. Par Messrs. Budge et Waller.—*Comptes Rendus, Académ. des Sciences*, tom. 33, page 37.

11. Observations sur la partie intra-cranienne du nerf sympathique et sur l'influence qu'exercent les 3^{me}, 4^{me}, 5^{me}, et 6^{me} paires de nerfs sur les mouvements de l'iris.—*Ibid.* tom. 33, page 418.

12. Nouvelle méthode pour l'étude du système nerveux, applicable à l'investigation de la distribution anatomique des cordons nerveux et au diagnostic des maladies du système nerveux, pendant la vie et après la mort. Par A. Waller.—Tom. 33, p. 606.

13. Troisième partie des recherches sur la pupille. Par Budge et Waller.—*Ibid.* tom. 34, page 164.

14. Nouvelles observations sur la régéneration des nerfs. Par A. Waller.—*Ibid.* tom. 34, page 393.

15. Recherches expérimentales sur la structure et les fonctions des ganglions. Par A. Waller.—*Ibid.* tom. 35, page 524.

16. Observations sur les effets de la section des racines spinales et du nerf pneumogastrique au-dessus de son ganglion inférieur, chez les mamifères. Par A. Waller.—*Ibid.* tom. 34, page 582.

17. Nouvelles recherches sur la regénération des fibres nerveuses. Par A. Waller.—*Ibid.* tom. 34, page 675.

18. Examen des altérations qui ont lieu dans les filets d'origine du nerf pneumogastrique et des nerfs rachidiens, par suite de la section de ces nerfs au-dessus de leurs ganglions. Par A. Waller.—*Ibid.* tom. 34, page 842.

19. Sixième mémoire sur le système nerveux. Par A. Waller.—*Ibid.* tom. 34, page 979.

20. Septième mémoire sur le système nerveux envoyé à l'Académie des Sciences. A. Waller.—*Ibid.* tom. 35, page 301.

21. Huitième mémoire sur le système nerveux A. Waller. —*Ibid.* tom. 35, page 561.

22. Neuvième mémoire sur le système nerveux, sur l'influence du grand sympathique sur la circulation. A. Waller. —*Ibid.* tom. 36, page 378.

23. Anatomical and physiological observations on the organ of vision, for the purpose of ascertaining the alterations caused

by the section of the optic nerve.—*Proceedings of Royal Society*, vol. 8, No. 18, page 8.

In this memoir the process of disorganization was applied to elucidate the course and distribution of the fibres of the optic nerves, before and after, and also at their point of decussation.

24. Account of experiments on the vagus and spinal accessory nerves.—*Ibid.* vol. 8, No. 20, page 69.

25. Observations microscopique sur la circulation du sang dans les vaisseaux de l'œil, vue en transparence sur le vivant. —*Comptes Rendus, Académie des Sciences*, tom. XLIII. du 29me Septembre, 1856.

The object of this memoir was to describe the circulation of the blood in the vessels of the iris, of the ciliary ligament and processes, and in the vasa verticosa of the choroid, as seen under high microscopic power during life.

26. Observations on the so-called process of voltaic narcotine.—*Med. Times and Gazette*, March 19, 1859.

27. Additional Observations on voltaic narcotism.—*Med. Times and Gazette*, June, 1859.

28. Experiments on some of the various circumstances influencing cutaneous absorption. — *Proceedings of Royal Society*, May 26, 1859.

The preceding three memoirs contain observations on various points relative to cutaneous absorption, and demonstrate that various poisons applied to the skin may be either completely inert or rapidly fatal to life, according to the menstruum in which the are dissolved.

29. On the mode by which the actiniæ kill their prey.—*Proceedings of Royal Society.*

In the memoir on the actiniæ the author demonstrates that the mode by which these zoophytes kill their prey is by the injection of an acrid poison, which when inserted into the mucous membrane on man, is found to possess extremely irritating properties.